U. S. DOE Stationary Fuel Cell Program

Virgin Islands
State Energy Office
November 18th – 20th 2003

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U. S. Department of Energy

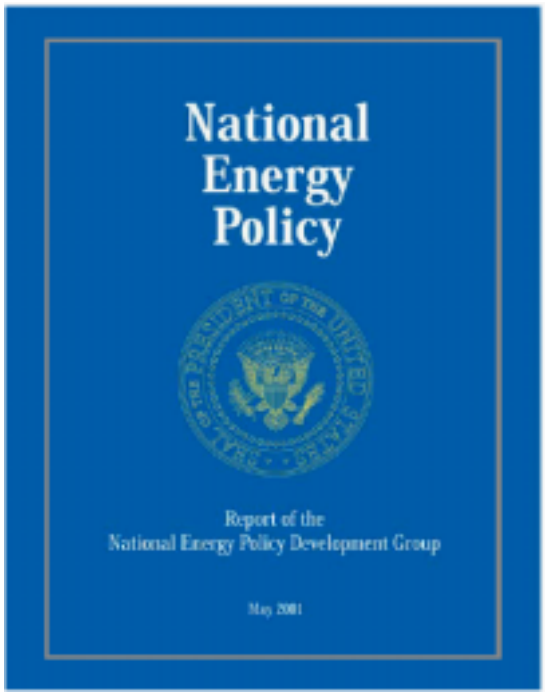
National Energy Technology Laboratory

NETL

Office of Fossil Energy

The Challenge

Defining a Path to World Energy Future

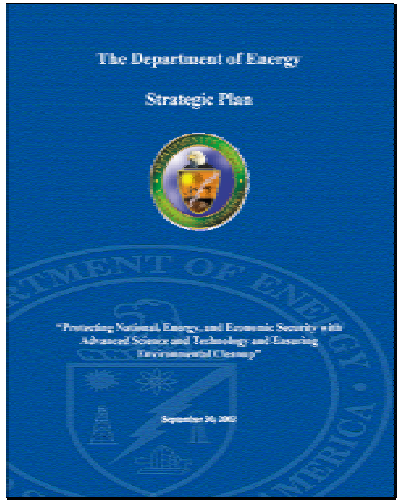


National Energy Policy

- Increasing America's domestic energy supplies
- Protecting America's environment
- Ensuring a comprehensive delivery system
- Enhancing national energy security

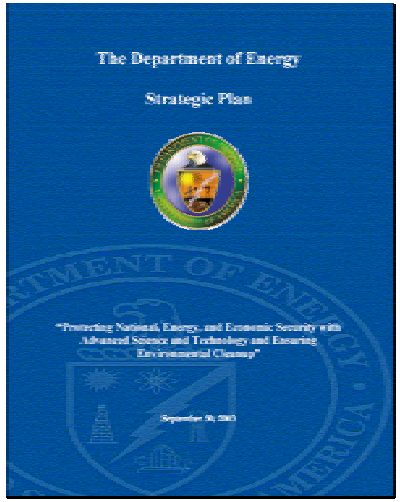
DOE Strategic Plan
September 30, 2003

Energy Strategic Goal: ***To protect our national and economic security by promoting a diverse supply and delivery of reliable, affordable, and environmentally sound energy.***



General Goal 4 − Energy Security: **Improve energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy by providing for reliable delivery of energy, guarding against energy emergencies, exploring advanced technologies that make a fundamental improvement in our mix of energy options, and improving energy efficiency.**

Strategies to Achieve Goals



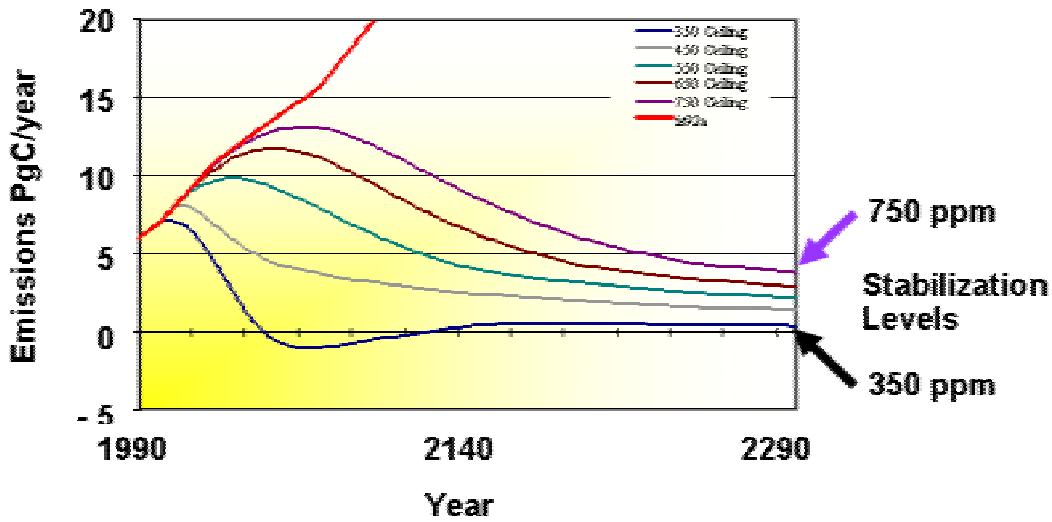
1. Partner with private sector, states and communities, national laboratories, colleges and universities, nongovernmental organizations, foreign allies, Congress and other Federal agencies to develop and bring to market technologies that advance energy efficiency.

9. Develop technologies to reduce the vulnerability and increase the reliability of the electricity supplies, focusing on superconducting materials and distributed generation including relatively small-scale and modular energy generation devices.

13. Collaborate with industry to develop fuel-cell power technologies for multiple applications, especially transportation.

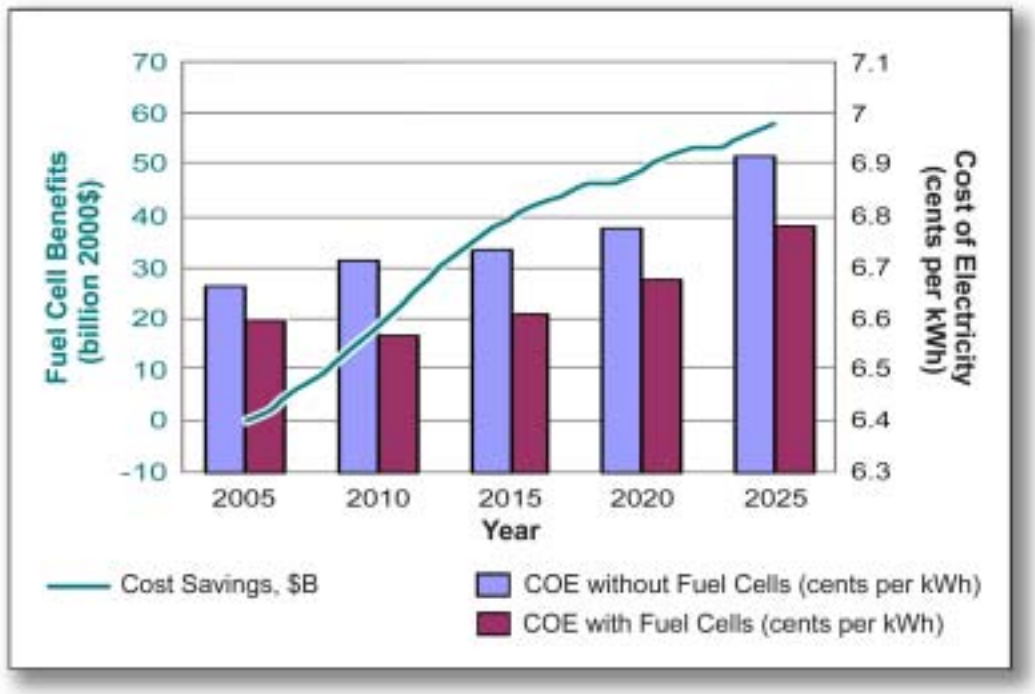
DOE Initiatives & Programs

- FreedomCAR
- Hydrogen Fuel Initiative
- FutureGen
- Clear Skies
- Climate Change
- Homeland Security
- Clean Coal Power



DG Fuel Cells
Cost Savings from Market Penetration

- **$50 billion cost savings from 72 GW by 2025**
  - 54.2 GW DG, 14.1 GW Central Power, 3.4 GW Buildings



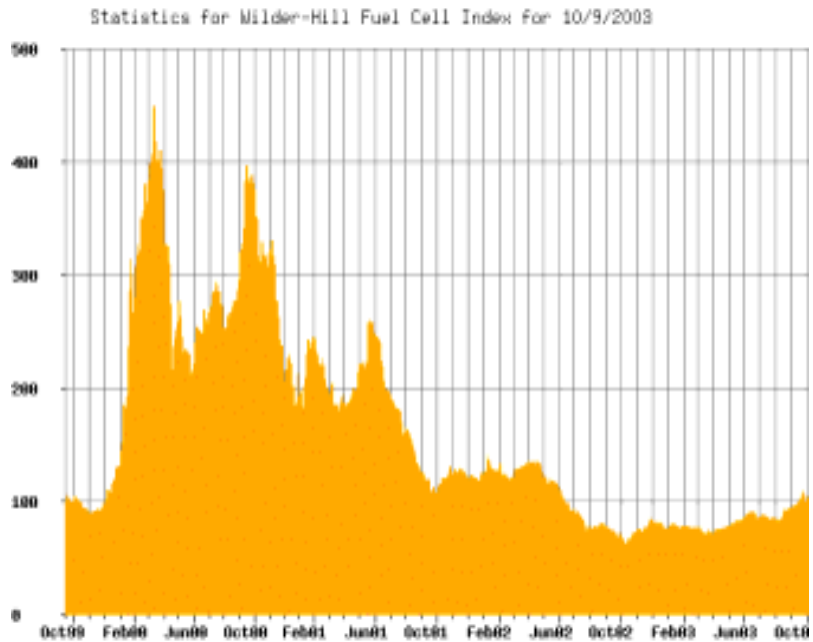
Source – EIA NEMS High Gas Price Scenario using FE Program Targets

Good News for Fuel Cells

- **DOE FreedomCAR and Hydrogen Fuel Initiative: $1.2B**
- **DOE FutureGen: a $1B, coal-based power & hydrogen**
- **World Bank-GEF-IFC issued January RFP for FC capital buydown in developing countries**
  - $2000/kW, $54M program
- **DOD capital buydown RFP issued in January ($1000/kW)**
  - **$3MM from DOD CERL, 10 new projects**
- **Several State programs/incentives**
- **World funding for SOFC has reached record levels**
- **Significant progress in planar SOFC configurations**
  - power density, fuel utilization, scale-up
- **SECA -- a major thrust of the U.S. DOE Fossil Energy R&D program**
  - Strong industry, laboratory and university participation
- **Transportation APU, military and micro-fuel cell market growing in size, applications and stock market interest**
- **Renewed interest in DG following 2003 blackout in New York**
- **Some Energy Bill provisions**

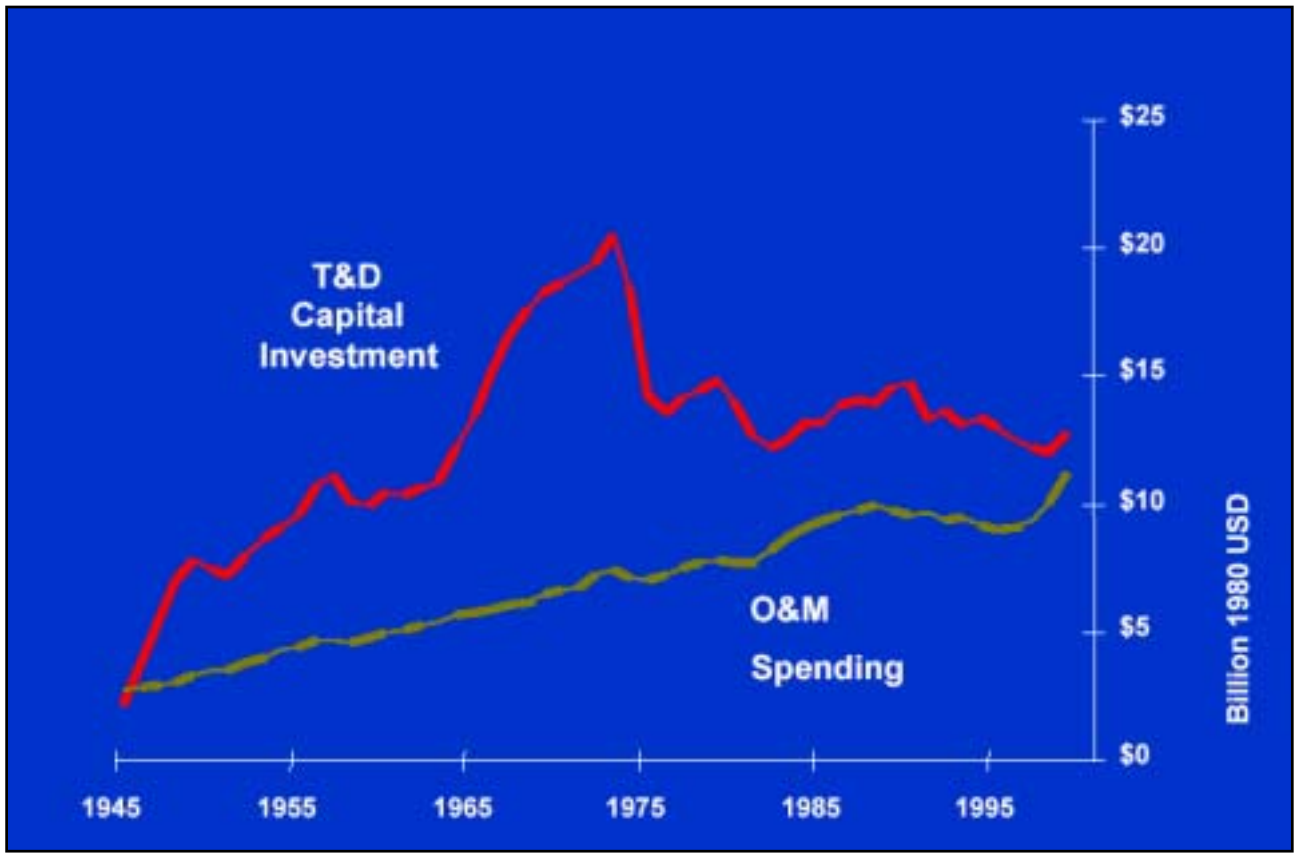
The Bad News for Fuel Cells

- **Stock market opportunity gone for now:**
  - Less venture/investment capital for companies
  - Premature disappearance of small fuel cell companies
  - Corporate R&D funding greatly reduced
  - Low corporate investment spending for non-PEMFC's
- **State funds threatened**
  - 44 states facing deficits
- **"Early adopter" market shrinking**
  - Sticker shock
  - Poor warranties
  - Technical problems
- **High natural gas prices**
- **Some Energy Bill provisions**



Source: The Hydrogen Fuel Cell Institute

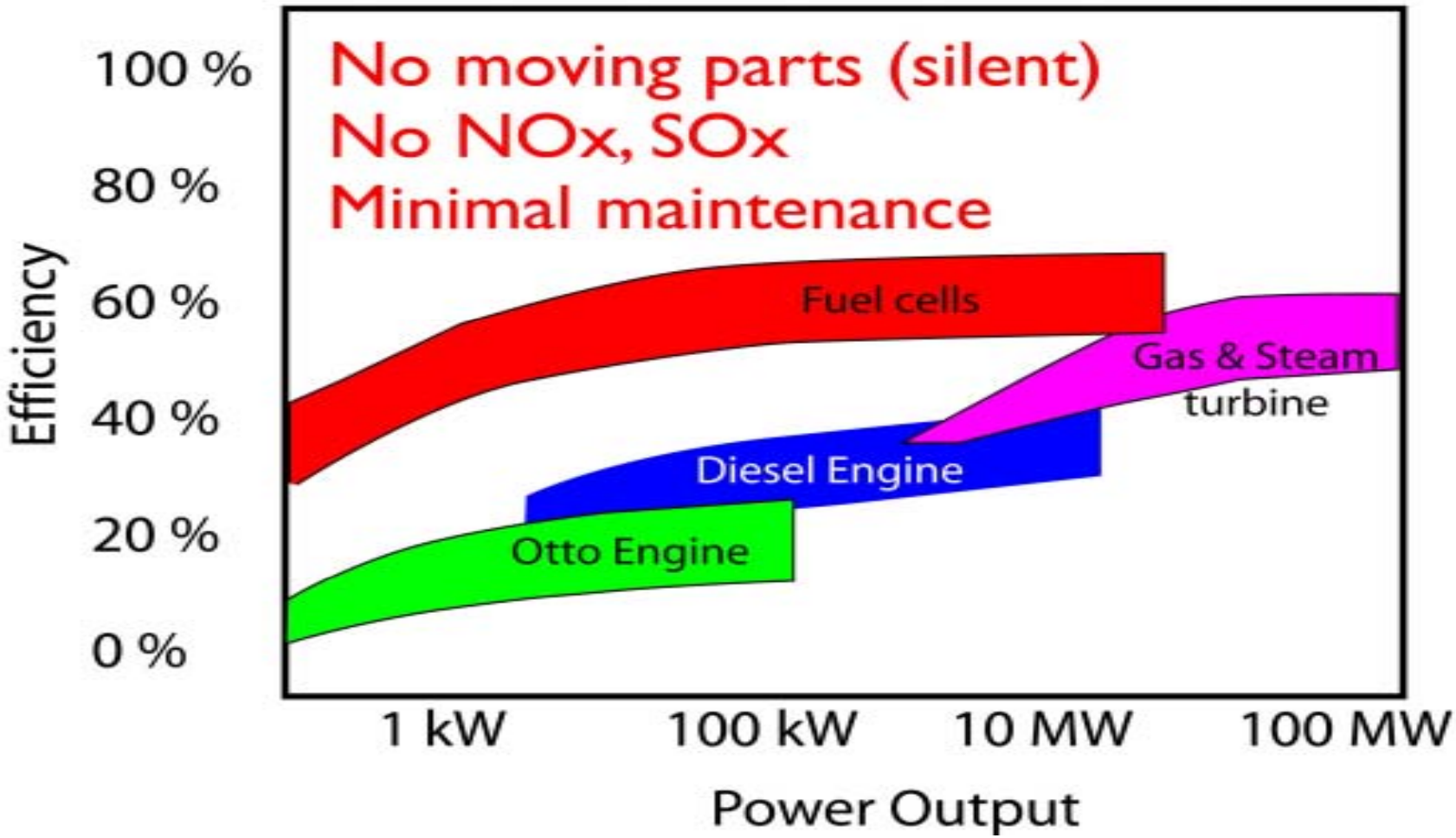
T&D Investments
A Key Reason for Consideration of DG



Asset base is reaching a critical age …35+ Avg.

Source: GE – Nicholas W.Miller, Jan 2003

Clean efficient power but must be cost competitive with existing power generation



Types of Fuel Cells

	SOFC	Molten Carbonate	Phosphoric Acid	Alkaline	Polymer Membrane
Electrolyte	Y_2O_3-Stabilized ZrO_2 (YSZ)	Li_2CO_3-K_2CO_3	H_3PO_4	KOH	Perfluoro-sulfonic acid
Cathode	Sr-doped $LaMnO_3$	Li-doped NiO	Pt on C	Pt-Au	Pt on C
Anode	Ni/YSZ	Ni	Pt on C	Pt-Pd	Pt on C
Temperature	800-1000°C	650°C	200°C	100°C	90°C
Fuel	H_2, CO	H_2, CO	H_2, CO	H_2	H_2

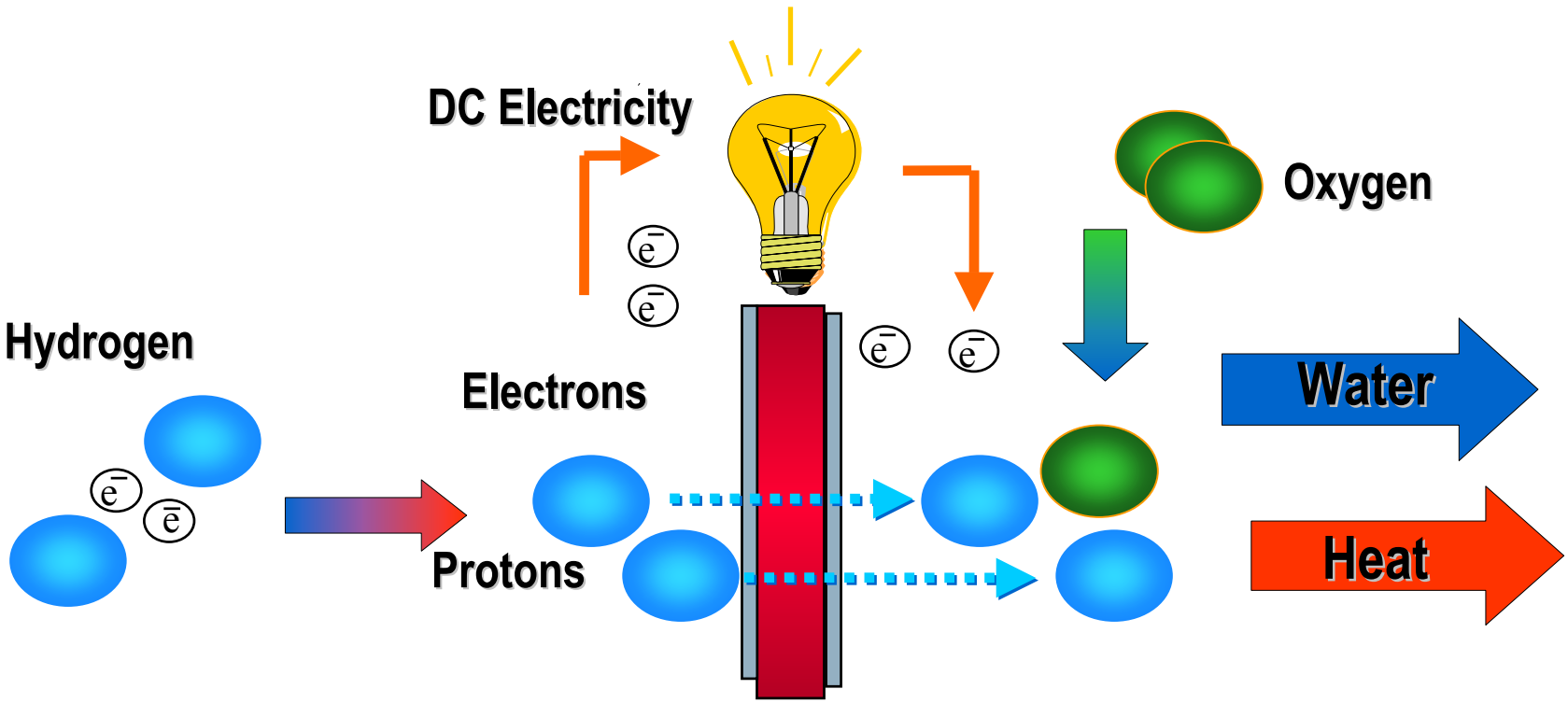
FUEL CELL TECHNOLOGIES

Fuel Cell Technology	Electrolyte	Operating Temperature	Efficiency (%)	
			Electrical	Overall
PEMFC	Ion exchange membrane	50 C	30-35	50-60
AFC	KOH	80 C	Low	Low
PAFC	Phosphoric Acid	200 C	36	80
MCFC	Alkali carbonates	650 C	45-55	75-80
SOFC - High Temp.	Solid metal oxide	980 C	45-47	75-80
SOFC - Reduced Temp.	Solid metal oxide	660 C	42-45	60-70

Source: SFCCG, Inc. (Aug. 1997)

Fuel Cell Process

Polymer Electrolyte Fuel Cell



$H_2 \Leftrightarrow 2H^+ + 2e^-$

0 Volts

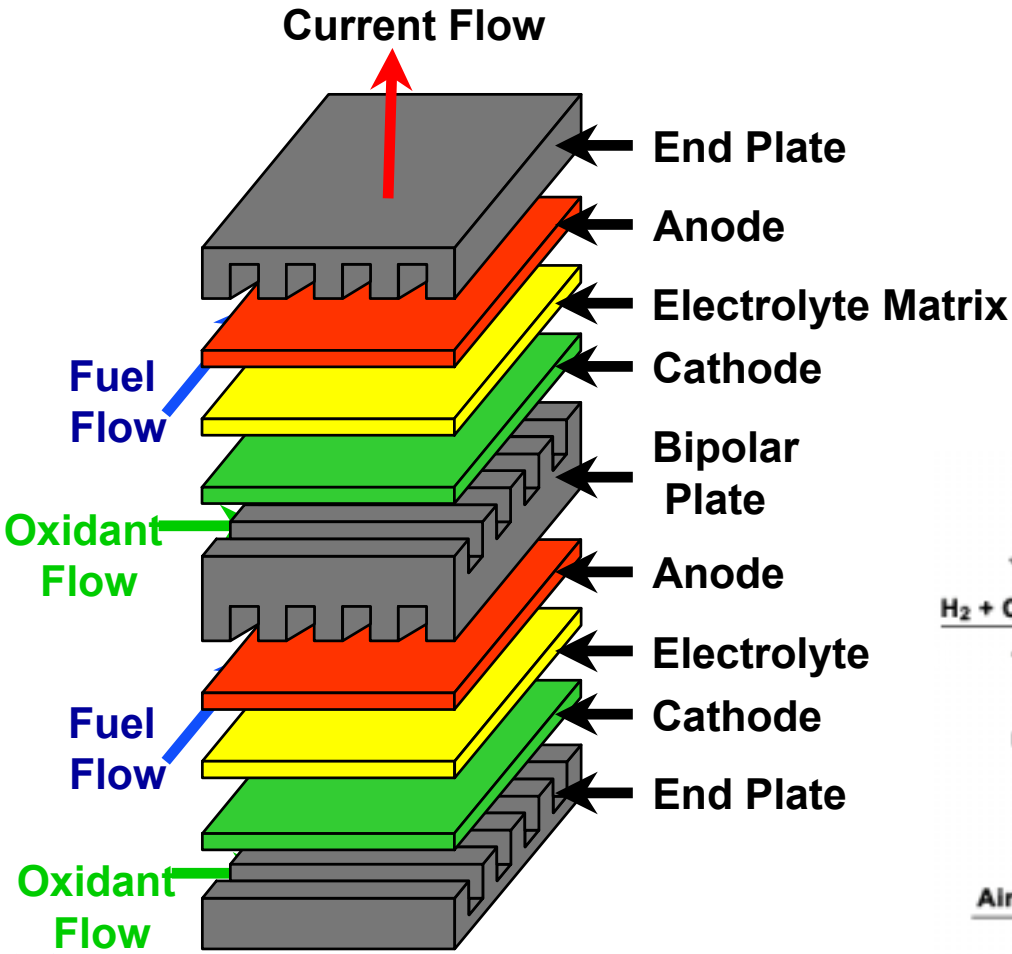
$H_2 + 1/2O_2 \rightarrow H_2O$

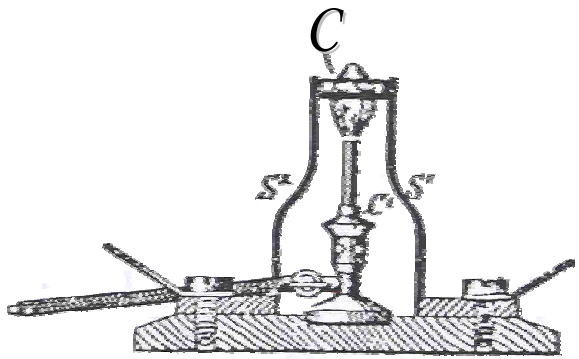
$1/2O_2 + 2e^- \Leftrightarrow 1/2O_2^{--}$

~1.23 Volts

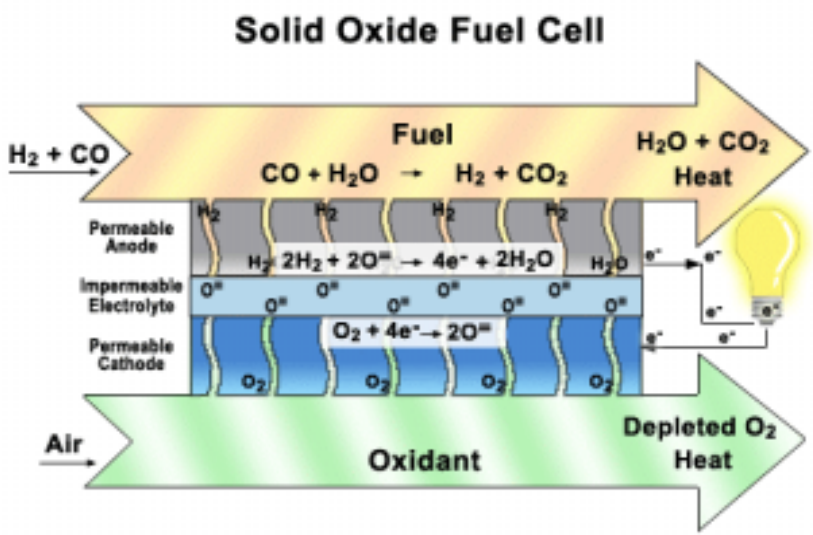
Approx. 1 volt or less/cell, therefore add cells together

Solid Oxide Fuel Cell

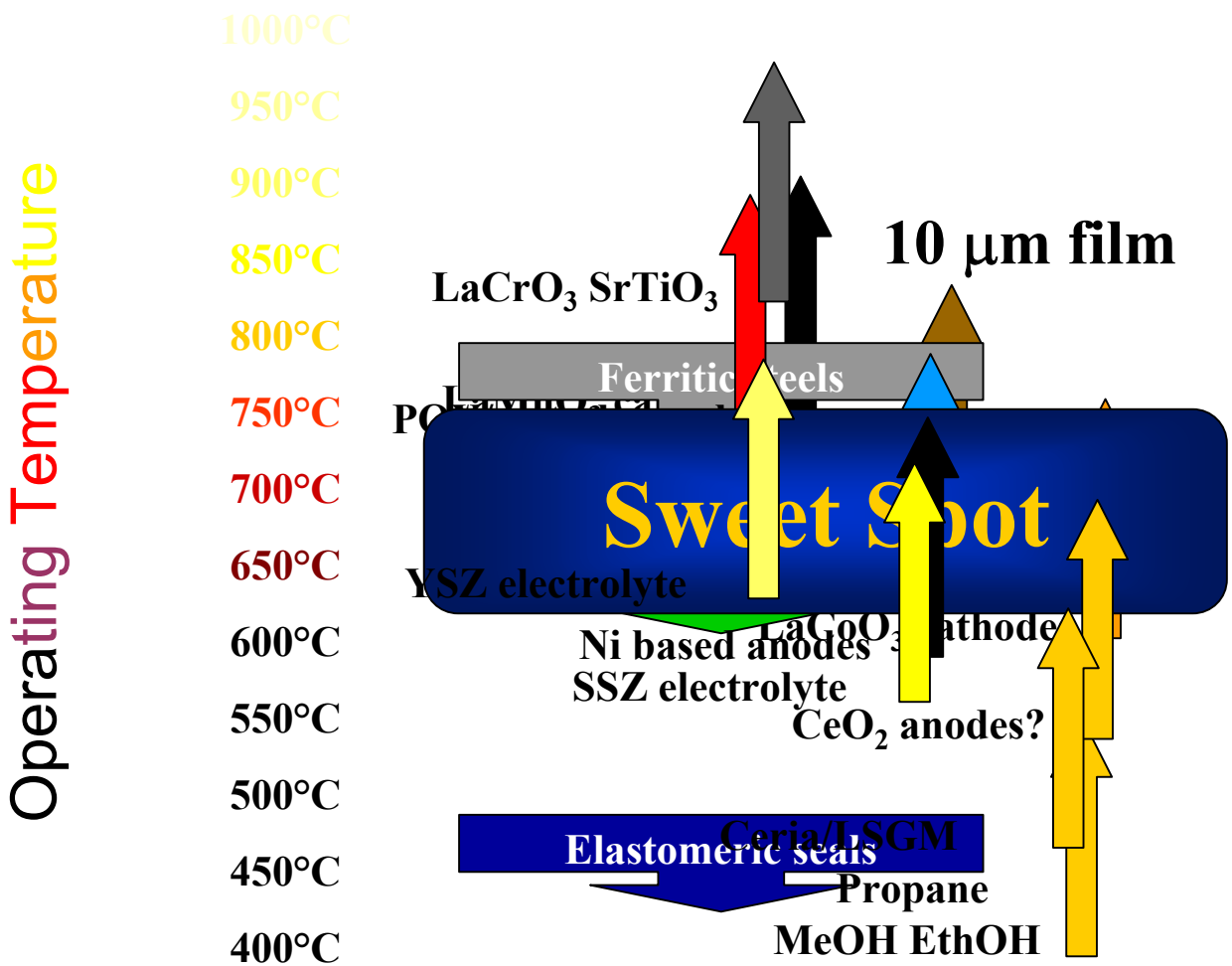




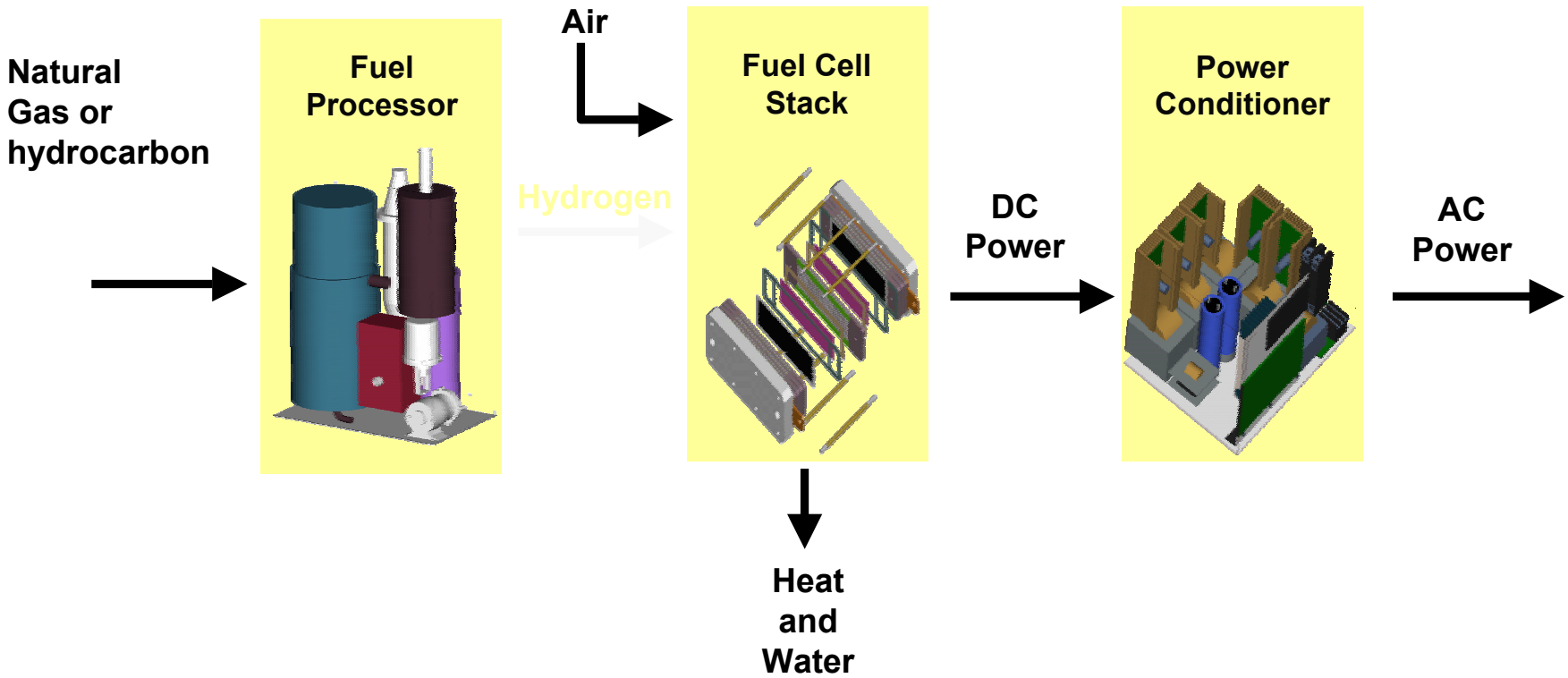
W. Nernst
"Electrical Glow-Light"
U.S. Patent 623,811 April 25, 1899



Designing a Fuel Cell



System Components



Integrated System

Fuel

Air

Water

AC Power

Heat

Fuel Processor

Power Generation

Inverter

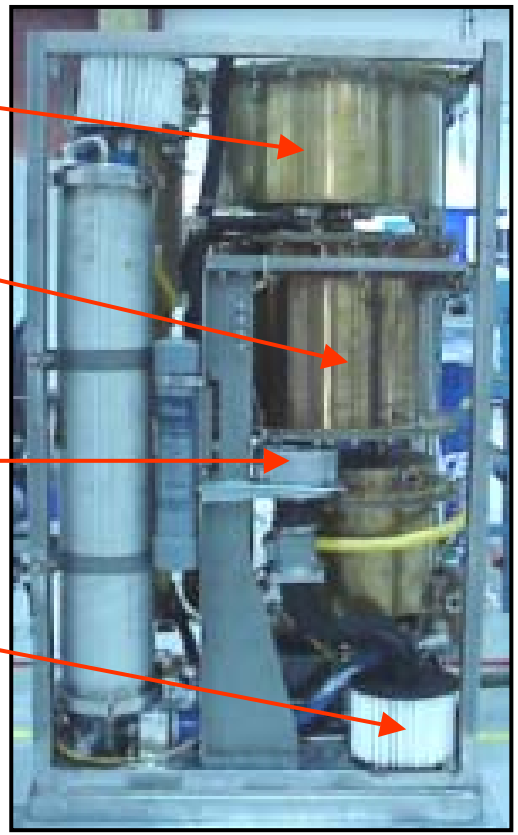
Fuel Processor

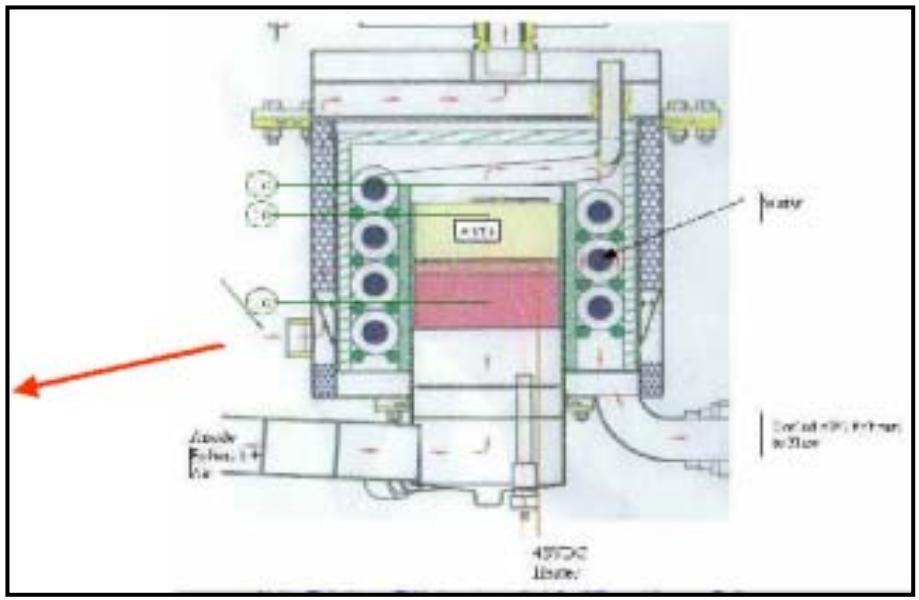
Prox

Main Reactor

ATO Blower

ATO Filter





Viewed with Fuel Processing

Module Side Panel Removed

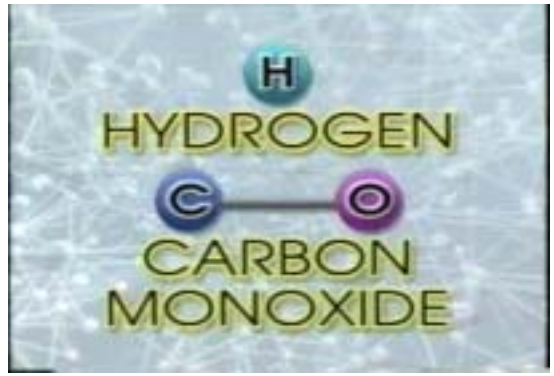
Tubular Solid Oxide Fuel Cells

2003

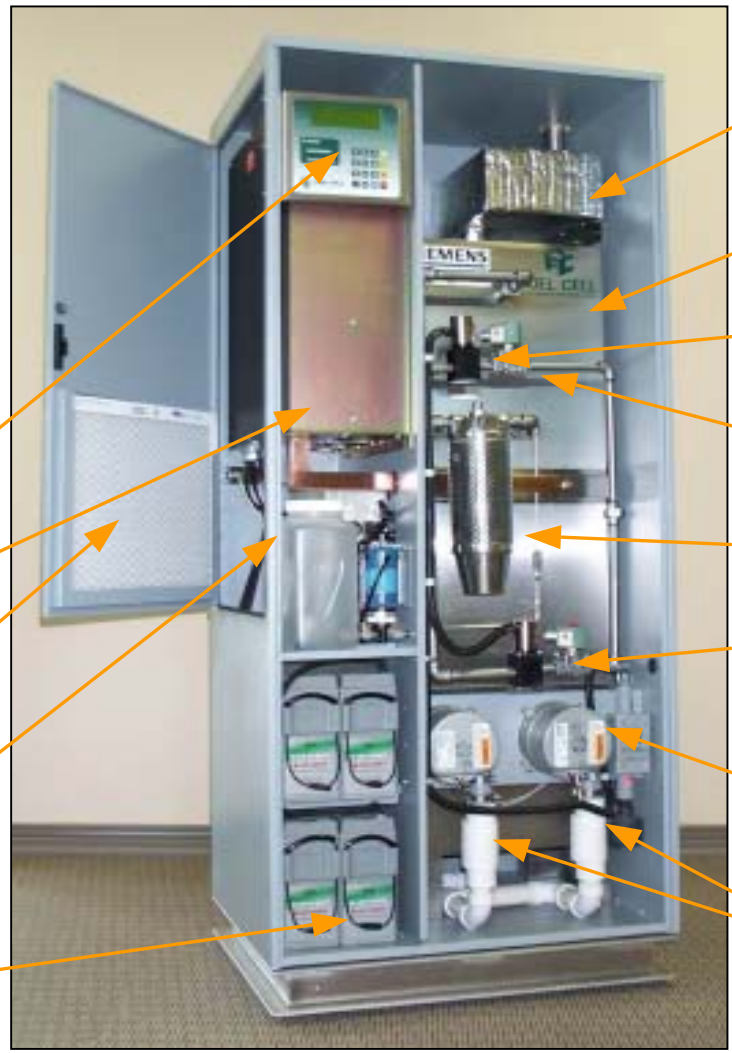
- 47% efficiency
- > $10,000/kW
- 100-220kW
- 70,000 hrs operation of 2 cells

2004-2008

- Near-term DG market
- 47- 63% efficiency
- Munhall, PA 15MW/yr manufacturing facility ($4500/kW)
- 250kW - 550kW
- $1,000-$1,500/kW



Siemens Westinghouse/FCT 5 kW System



Data Display

10 kW DC/AC Inverter

Inlet Air Filter

Control Computer and Electronics

Lead/Acid Battery Pack

Exhaust Heat Exchanger

Siemens-Westinghouse 5 kW Cell Stack

Gas Control Valve For Start-up Heater

Gas Shut-off Valve For Start-up Heater

Desulfurizer

Cell Stack Gas Control Valve

Cell Stack Gas Shut-off Valve

Primary and Backup Air Blowers

Molten Carbonate Fuel Cells

2003

- Demonstration
- 47% efficiency
- $2,500-5,000/kW
- 250kW
- Internal reforming
- Torrington, CT manufacturing facility 50MW/year

2004-2008

- Near-term DG market
- 54% efficiency
- $1,000-1,500/kW
- 250kW-3MW

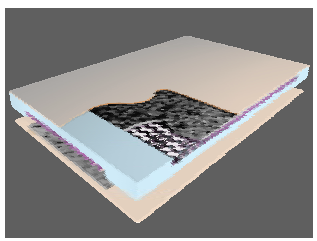
FuelCell Energy Products

Building block approach provides scalability and a standardized product to manufacture

Sub-MW Power Plant

Sub-MW Module

Stack



Fuel Cell

MW Module

MW Power Plant

Phosphoric Acid Fuel Cells

1993

- "Commercially ready"

2002

- 250+ 200kW units
- ~40% efficiency
- $4,500/kW
- 95-98% availability
- 4 million customers
- 4 million hours
- 99.99-99.9999 reliability

DoD cost-shared in 3/4 of units

Cost of Electricity

COE = 0.125CC/H + 3.412FC/eff +O&M/H

CC - $4500/kW
Eff – 42%
O&M – 20
Hours – 7,000
FC - $6/MBtu

SECA Industrial Teams

FuelCell Energy

DELPHI Battelle

Driving Tomorrow's Technology

Stacks provided by Global Thermoelectric

General Electric Company

SIEMENS Westinghouse

Acumentrics

Advanced Power & Energy Technologies

Power Generation

SOFCo

NETL

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